

PATENT SPECIFICATION

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DRAWINGS ATTACHED

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(54) IMPROVEMENTS IN OR RELATING TO METHODS OF MANUFACTURING SEMICONDUCTOR COMPONENTS

(71) We, SIEMENS AKTIEN-GESELLSCHAFT a German Company of Berlin and Munich, Germany, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to methods of manufacturing semiconductor components, in particular integrated circuits, by use of known holograms in conjunction with photo-etching techniques, in which a semiconductor body is coated with a photo lacquer and exposed to light to form an etching mask prior to each etching or further processing operations.

The use of holographic projection to form the required etching patterns without requiring a photographic mask to lie in contact with the semiconductor body is described, for example, in an article entitled "Holographic Projection of Microcircuit Patterns" published in Electronic Letters, February 1968 Vol. 4, No. 3. The process exploits the possibility of reconstructing a holographically recorded object as real physical image with a high degree of resolution. The etching pattern to be applied to the basic body serves as an object, and the surface of the semiconductor body, coated with photo lacquer, is arranged in the plane in which a real image of the etching pattern is formed during the reproduction process.

The holographic projection of an etching pattern offers several advantages, in comparison with the generally employed contact copying method, since each hologram can be used repeatedly, whereas an etching mask which has to be placed in direct contact with the basic body has a short life, since it is subjected to mechanical stress, and is sensitive to dust and scratches.

Particularly in the production of integrated circuits, where the basic body of

semiconductor material must be illuminated consecutively with various etching patterns, one for each further processing, and a problem then occurs, as it is necessary to ensure that each etching pattern to be applied is projected with a precise alignment, relative to the preceding pattern or patterns. The requisite adjustment of the basic body is more difficult than is the case when using the contact copying method, inasmuch as adjustment must be effected for tilt, as well as focus and lateral displacement, whereas with contact copying it is only necessary to provide means for observation of marks applied to the etching mask and the basic body, which are merely brought to coincidence. The physical separation of the basic body from the hologram which contains the etching pattern prevents the use of such a simple alignment process.

One object of the present invention is to provide a method which facilitates the adjustment of the particular hologram used, or of the real image of the etching mask reconstructed from the hologram, with the etching pattern or patterns already located on the basic body.

The invention consists in a method of manufacturing semiconductor components, using photo-etching techniques, in which a basic body of semiconductor material is coated with a photo lacquer and exposed to produce an etching pattern before each processing step, and in which each of said etching patterns is projected from a respective hologram, the hologram used for the production of the first etching mask having at least three adjusting marks recorded therein, the projections of which are imaged on said body to provide reference marks to facilitate resetting during the projection of each subsequent hologram, said reference marks remaining on the surface of said body as discrete reflective areas after the execution of the first photo etching process, each subsequent

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hologram having said at least three adjusting marks recorded thereon, so that the real images of said adjusting marks are reconstructed during the reproduction of each subsequent hologram and brought to coincidence with the respective reference marks present on the basic body by adjustments using an observation device to obtain the maximum spacing of any interference rings produced between a reflected adjusting wave formed by the real image of each adjusting mark reproduced from the particular hologram and reflected from the corresponding reference mark and a respective comparative wave that is formed by the virtual image of the associated adjusting mark upon reproduction of that hologram.

The invention exploits the fact that by means of an adjusting process based on interference fringes, a simple adjustment can be effected to an accuracy of a fraction of a wave length of the light used, as even small maladjustments lead to well-defined interference rings. When applied to the industrial production of large numbers of integrated circuits, this adjusting process enables the electrical characteristics of the individual circuits to be maintained within very narrow tolerance limits, and so renders superfluous the frequent sampling of circuits that is normally required to ensure approximately constant characteristics are maintained during production.

In order to avoid unwanted illumination of the basic body during each resetting process, it is advantageous if each hologram used after the initial exposure has the adjusting marks recorded and reproduced with light of a wave length which does not influence the photo lacquer on the semiconductor body.

In an alternative method of avoiding unwanted illumination of the body during resetting, the body is covered with a mask which only exposes the reference marks on the body. Illumination of the reference marks on the basic body during resetting does not have a disturbing effect, as these regions will in any case be illuminated when the actual etching pattern is projected after removal of the mask, because the adjusting marks are recorded together with the etching pattern in the hologram.

The observation device can be arranged in the region of interference between the reflected adjusting waves formed by the real image of the adjusting marks reconstructed from the hologram and reflected back to that side of the hologram which lies opposite the basic semiconductor body and the comparative waves comprising the reconstructed vertical images of the adjusting marks, the body then being moved by means of an adjusting device capable of

adjustment in all directions, and of being clamped in the adjusted position.

Either plane or volume holograms may be employed. In contrast to a plane hologram, where the recorded interference field is retained in a thin surface layer, in a volume hologram, it is formed in layer having the thickness of a plurality of wave lengths of the light used. The volume hologram is formed in such a manner that reproduction produces a real image of the etching pattern and of the adjusting marks contained therein on one side of the hologram and on the other side of the hologram produces a virtual image of the adjusting marks, the virtual image having points of origin which coincide with the corresponding real image points.

In order to be able to facilitate observation of the interference field, it is advantageous if the hologram is recorded in such manner that it reproduces the adjusting marks with a higher luminosity than that of the etching pattern. A further simplification is obtained if the hologram reproduces the adjusting wave with such an intensity that in the region of its interference with the comparative wave it has approximately the same intensity as the comparative wave.

The hologram may be formed in such a manner that the adjusting marks and the etching pattern are stored in different parts of the hologram.

The invention will now be described with reference to the drawings, in which:—

Figure 1 schematically illustrates the illumination of a plane hologram, in one exemplary embodiment of the invention;

Figure 2 illustrates the reproduction of the hologram referred to in Figure 1.

Figure 3 is an explanatory illustration of the interference field used for resetting adjustments;

Figure 4 shows the recording of an etching mark in a volume hologram;

Figure 5 shows the illumination of this volume hologram to record the comparative wave; and

Figure 6 shows the reproduction of this volume hologram.

For the recording of a plane hologram, as shown in Figure 1, an etching mask 1, serving as object, and containing the etching pattern and the adjusting marks, is illuminated with a coherent light wave to produce an object wave 2, which is brought into interference with a reference wave 3, to form an interference pattern that is retained in the photo-sensitive layer of a hologram carrier 4. During this illumination each adjusting mark on the mask 1 produces a spherical wave 5 illustrated in the region of the object wave. After development, a resultant hologram 6

is obtained, and reproduction of the hologram 6 is effected, as shown in Figure 2, with the aid of a reproduction wave 7, which has the same frequency and physical geometry as the reference wave 3 used during recording, but the hologram 6 is rotated by 180° in comparison with the recording position. With this geometrical arrangement for illumination of the hologram, two output waves are produced, a reconstructed object wave 8 that passes through the hologram, and a comparative wave 9 that is reflected back from the hologram. The reconstructed object wave 8 forms a real image and the comparative wave 9 forms a virtual image of the recorded etching pattern and the adjusting marks contained therein. The origin points of the virtual image formed by the comparative wave 9 coincide in position with the corresponding points of the real image. A body 10 of semiconductor material is mounted by means of a holding device (not illustrated) in an already preadjusted position in the region of the real image of the etching pattern. For the first illumination of the basic body, the surface of which is designed to be reflective to the coherent illuminating waves, the body is simply adjusted in such manner that the real image of the etching pattern falls in the light-sensitive surface layer of the basic body. Thereafter, for each exposure, in the correctly adjusted position of the basic body, those components of the wave 5 representing the real images of the adjusting marks are reflected back, so that each forms an adjusting wave 5' reflected by the surface and passing back from the reference mark through the hologram to form an interference pattern with the comparative wave 9. The maximum spacing of the interference rings is set with the aid of an observation device 11 arranged in the region of the comparative wave. The observation device in this embodiment consists of a camera tube 11' connected to a display device 11''. In the event of exact adjustment, the interference bands completely disappear. In order that the etching pattern, likewise visible in the observation device 11, should not have a disturbing effect, the adjusting marks are recorded to form reference marks with an intensity greater than that of the etching pattern, by means of a subsequent illumination of the adjusting marks, for example. During the adjustment of the basic body the latter is covered with a mask which does not transmit light, but which is provided with openings at the points of the reference marks, in order to prevent undesired illumination of the photolacquer. As the exposed reference marks are to remain

in existence as discrete reflective areas, for use during the resetting for subsequent illumination processes a negative photo lacquer is employed for the light-sensitive layer, so that the illuminated points remained unetched.

The formation of the interference field used for resetting adjustment is illustrated in Figure 3. For simplification of the illustration, the distance of the hologram 6 from the basic body 10 is shown on a drastically reduced scale, and of the plurality of individual waves formed during reproduction of the hologram, only one adjusting wave 5 and its associated comparative wave 9 are illustrated. The body 10 is shown in a mal-adjusted position, the correctly adjusted position 10' being shown in broken line fashion. The adjusting wave reflected by the reference mark on the body passes through the hologram 6, and is superimposed upon the comparative wave 9. The reflection from the mal-adjusted body causes the centre to the reflected adjusting wave 5' to appear displaced to an image point 12. As the virtual image origin point 12' of the comparative wave 9 emerging from the hologram does not coincide with the image point 12, the superimposition of the two waves causes interference rings to be formed, which are indicated by small circles drawn at the intersection points of the wave fronts. Adjustment of the body to remove, or obtain maximum ring spacing, for all three marks ensures that the body is precisely reset.

The illumination of a volume hologram 13 to form an etching pattern and the adjusting marks contained therein, can take place, as shown in Figure 4, in a manner similar to that used for a plane hologram as described with reference to Figure 1.

The reference wave 3 is brought into interference with the object wave 2. After photographic development, the hologram 13 will contain approximately parallel dark areas normal to the surface of the hologram. In the reproduction of a volume hologram of this kind, a real image of the etching pattern and of the adjusting marks will be obtained for the illumination of the basic body, but in contrast to the surface hologram, there will be no reflected comparative wave if further steps are not taken.

Therefore, the adjusting marks are also recorded in an additional illumination process, as shown in Figure 5. Here the adjusting marks are illuminated with the aid of an optical device 14, and the waves 5 emitted by said marks are brought into interference with a reference wave 3', which is incident from the opposite side of the hologram. The areas in which the two waves

are superimposed with the same phase run approximately parallel to the illuminated surface of the hologram.

Figure 6 shows the reproduction of the complete hologram recorded in accordance with Figure 4 and 5, the complete hologram 13 being illuminated with the reproduction wave 7, which is of the same geometry and frequency as the reference wave 3 and 3' used for recording. The hologram is rotated by 180°, in comparison to the recording arrangement, and there is now obtained, as was the case in the reproduction of the plane hologram, a real image of the etching pattern together with the adjusting marks on one side of the hologram, and on the other side of the hologram a virtual image of the adjusting marks, the virtual image origin points of which coincide with the corresponding real image points. An interference field is formed here by the superimposition of the reflected adjusting-waves and the comparative-waves, and can be observed through the observation device 11, just as described with reference to Figure 2.

WHAT WE CLAIM IS:—

1. A method of manufacturing semiconductor components, using photo-etching techniques, in which a basic body of semiconductor material is coated with a photo lacquer and exposed to produce an etching pattern before each processing step, and in which each of said etching patterns is projected from a respective hologram, the hologram used for the production of the first etching mask having at least three adjusting marks recorded therein, the projections of which are imaged on said body to provide reference marks to facilitate resetting during the projection of each subsequent hologram, said reference marks remaining on the surface of said body as discrete reflective areas after the execution of the first photo-etching process, each subsequent hologram having said at least three adjusting marks recorded thereon, so that the real images of said adjusting marks are reconstructed during the reproduction of each subsequent hologram and brought to coincidence with the respective reference marks present on the basic body by adjustments using an observation device to obtain the maximum spacing of any interference rings produced between a reflected adjusting wave formed by the real image of each adjusting mark reproduced from the particular hologram and reflected from the corresponding reference mark and a respective comparative wave that is formed by the virtual image of the

associated adjusting mark upon reproduction of that hologram.

2. A method as claimed in Claim 1, in which the adjusting marks in each subsequent hologram are recorded thereon and reproduced therefrom by light of a wave length which does not influence the photo lacquer.

3. A method as claimed in Claim 1, in which said basic body is covered during each resetting process by a mask which only exposes the reference marks on said body.

4. A method as claimed in any preceding Claim in which an observation device is arranged in the vicinity of the virtual image of the adjusting marks reconstructed from each hologram on the side of the hologram which lies opposite the body.

5. A method as claimed in Claim 4, in which each of said holograms is a plane hologram.

6. A method as claimed in Claim 4, in which each of said holograms is a volume hologram, which on reproduction produces on one side of the hologram a real image of the etching pattern and of the adjusting marks contained therein, and on the other side thereof produces a virtual image of the adjusting marks, the virtual image origin points of which coincide with the corresponding real image points.

7. A method as claimed in any one of Claims 4 to 6, in which each of said holograms reproduces the adjusting marks with a higher luminosity than that of the etching pattern.

8. A method as claimed in any one of Claims 4 to 6, in which each of said holograms reproduces the virtual images of said adjusting marks with such an intensity that in the region of interference with the reflected real images both waves have substantially the same intensity.

9. A method as claimed in one of the Claims 4 to 8, in which each of said holograms contains the adjusting marks and the etching pattern stored in different parts of the hologram.

10. A method of manufacturing semiconductor components, substantially as described with reference to Figures 1 to 3, or Figures 4 to 6.

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COMPLETE SPECIFICATION

4 SHEETS

*This drawing is a reproduction of
the Original on a reduced scale
Sheet 1*

Fig.1

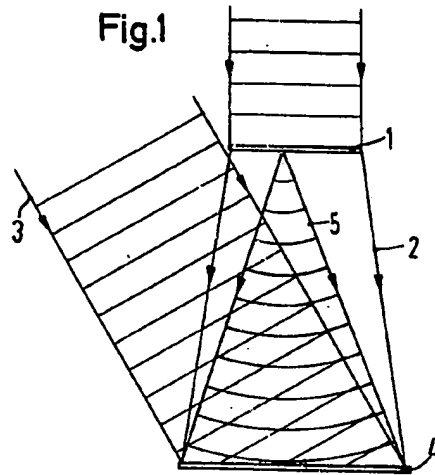
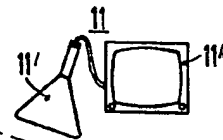
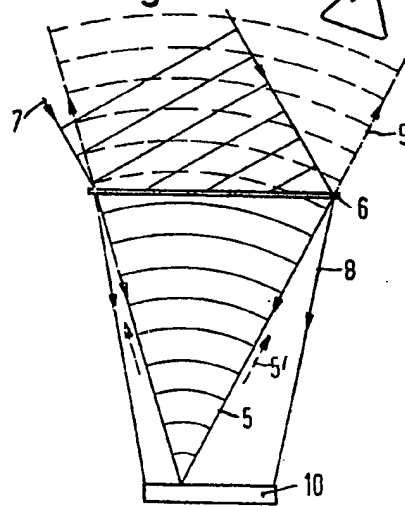


Fig.2



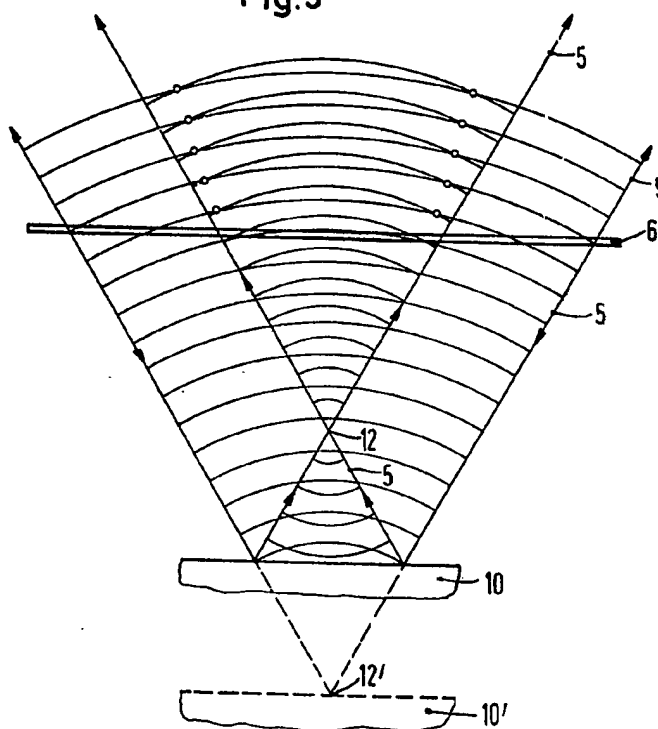
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COMPLETE SPECIFICATION

4 SHEETS

*This drawing is a reproduction of
the Original on a reduced scale*
Sheet 2

Fig.3



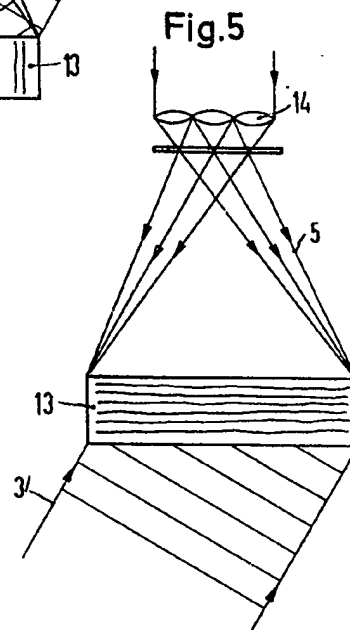
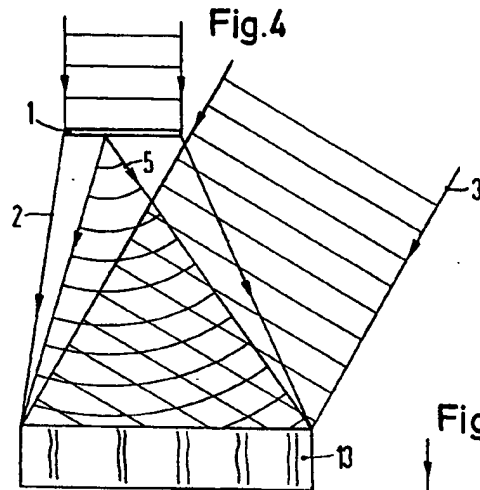


Fig.6

